Sustainable polygeneration of electricity and water

Summary

Cooling water from power plants can power desalination and water re-use.

Production of water in a low pressure membrane separation process can be powered by waste heat from both conventional and solar power plants and bring additional revenues to the plant operator.

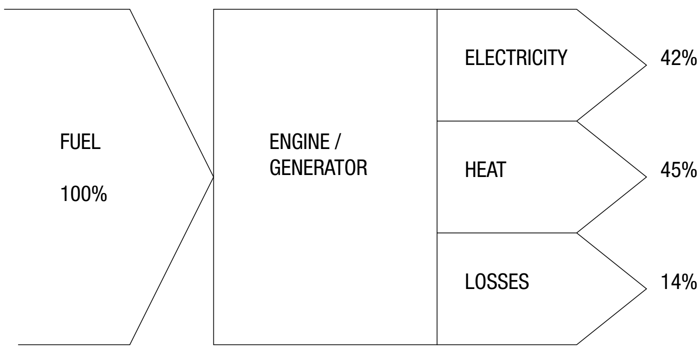
Polygeneration

In the long term, solar energy will provide sufficient energy for all human activities on the earth. The daily influx of energy from the sun is more than a thousand times larger than our present use of all types of energy.

While existing energy infrastructure, especially power plants, has been built on the false assumption of growing and non-ending supply of fossil fuels, new more sustainable energy technologies are today in rapid development. The lead in development of specific technologies is often taken by small or medium size specialist companies, but the large international infrastructure companies ("integrators") are looking for ways to integrate these new technologies both in new and in existing infrastructure in an efficient way.

One of the new concepts that have evolved recently is the co-location of power plants and water works. The most powerful model is one that extends the co-location concept to the co-generation concept and then further into the polygeneration concept.

NORMAL FIGURES FOR COMBINED HEAT AND POWER (CHP)



Scarab uses the heat for
purification/desalination of water

A power plant turns fuel into electricity and heat. The figures are from an efficient power plant. Often the percentage of electricity produced from the fuel is much less.

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Co-location means that power utilities and water utilities are placed next to each other and can use some of the same facilities, but also get close to each others produce, since water plants need electricity and power plants need water.

Co-generation usually means that the same plant produces both electricity and heat. In traditional power plants half the fuel usually goes to waste. Not only is the fuel not put to good use, the heat produced has to be removed by heat-exchangers into rivers or lakes or into the air with costly cooling towers. Using that energy for practical and valuable purposes obviously makes sense.

A proven co-generation concept is the district heating system, very common in Sweden, where waste heat from power plants is used for hot water or heating in buildings. Another is the CHP (Combined Heat and Power) concept that has been introduced especially in the US to provide electricity to individual houses, shops etc. The Swedish district heating systems are large – in the megawatts while some of the CHPs are very small – tens of kW. So, there is experience of a very wide range of capacities.

The efficiency of co-generation is obvious. Yet many power plants waste as much heat energy as they deliver in electricity. The reason is that there is no conventional use for the heat at the location or in the vicinity. Therefore the new concept of polygeneration has been developed.

Polygeneration means **using several different fuels in several different processes to produce a range of different results/products**. The purpose is both to save on resources and increase profitability.

During the last decades, researchers around the world have fine tuned the polygeneration concept. New fuels have been added, efficiency has been increased as well as internal energy recovery and new uses of energy. Today a standard polygeneration system may use coal, oil, natural gas, biomass, municipal waste or solar collectors alone or in combination to provide electricity, process steam, district heating, hot water and various types of cooling.

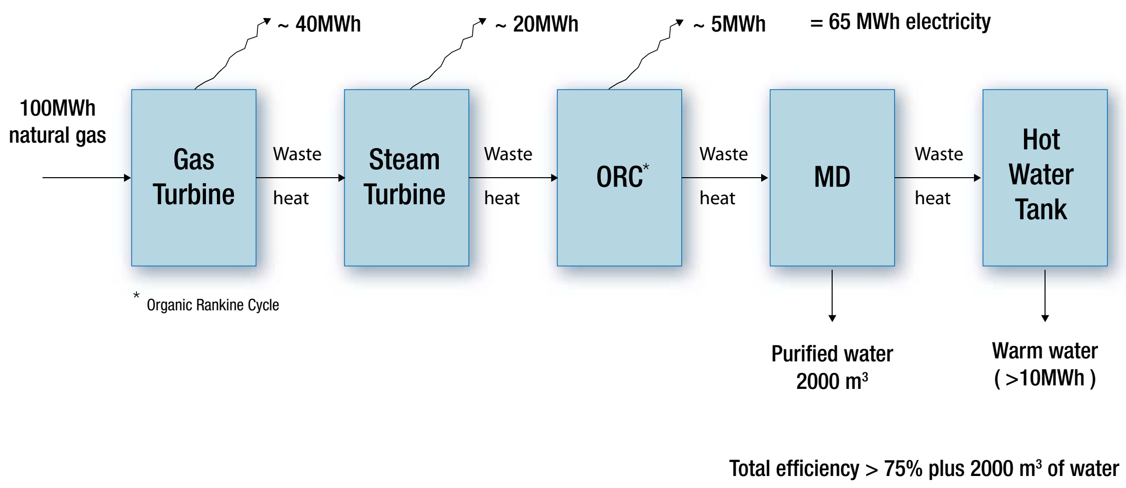
Scarab has added yet another dimension by developing and introducing a low grade heat powered water purification/desalination technology. By using waste heat, energy use for water treatment is reduced at least four times compared to comparable existing methods.

Polygeneration in one form or another will be the most economical choice for future implementation of energy and water infrastructure developments from the smallest scale to the largest.

Typical applications of polygeneration are:

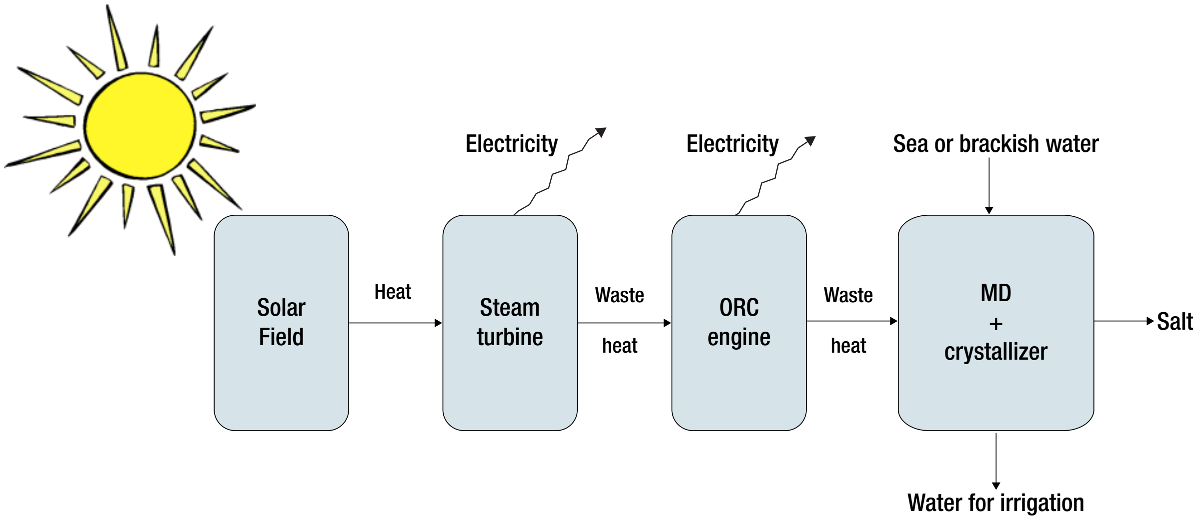
1. Any conventional power plant can be made more efficient and sustainable in polygeneration mode.
2. Solar powered CHP for single houses or small communities producing electricity, hot water, space heating, pure water, space cooling and refrigeration.
3. Small PV for electricity production co-producing hot water and pure water.
4. Large concentrated solar power steam engine plants, possibly topped up with biomass burning to increase initial temperatures and to permit 24-hr production. This plant could for instance concentrate on delivering electricity and desalinating water if located in a sparsely populated area and be complemented with for instance hot water and space cooling if located in a populous area.
5. Large PV field for production of electricity and pure water
6. Gas-engines using biogas from agricultural or municipal waste to produce electricity and pure water.
7. There are a large number of other variations on the polygeneration theme. In general, saving energy in existing plants, making energy production more efficient in new and existing plants and using the same fuel for multi-purposes whenever possible is more profitable and also more sustainable than just adding new production facilities whether of conventional or new ("alternative" energy) types.

POLYGENERATION FOR ENERGY EFFICIENCY



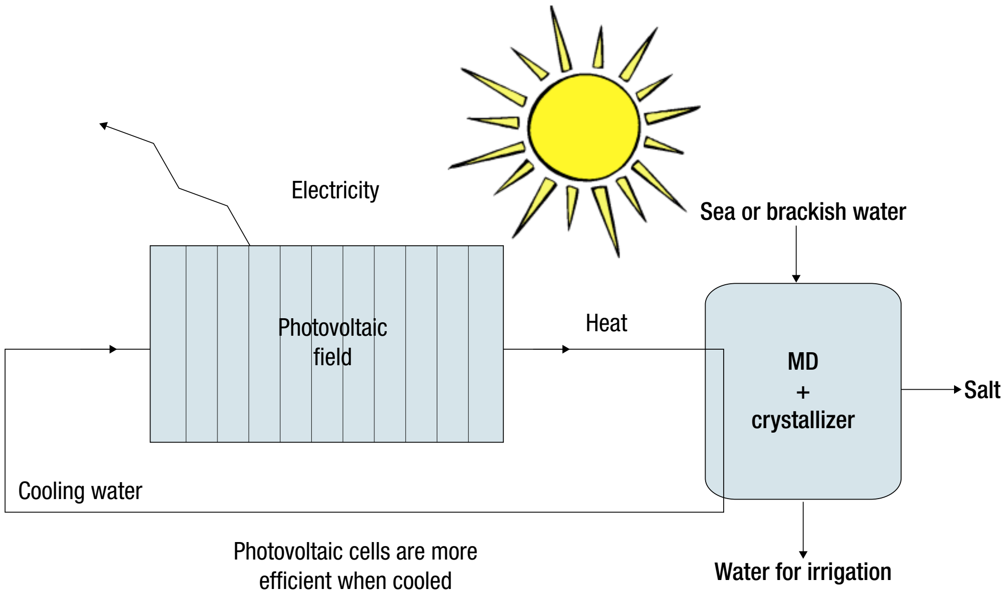
Conventional "combined cycle" power plant in polygeneration mode

CONCENTRATED SOLAR POWER POLYGENERATION



Concentrated solar power plant in large scale application

CONCENTRATED PHOTOVOLTAICS POLYGENERATION



Photovoltaic polygeneration in large scale application

Membrane distillation – a new technology for water treatment and desalination

Status of the technology

International research on membrane distillation took off in the 1980-ies when Scarab Development AB was awarded its first patent describing what is now known as Air Gap Membrane Distillation. Since then hundreds of researchers have published theoretical papers on the technology and various tests have been reported as well as a few different types of prototypes.

Prototype equipment has been developed by TNO / Keppel Seeger, Fraunhofer / Solar Spring Memsys and Scarab. All these companies have individual approaches to the commercial exploitation and each has targeted specific market niches.

Apart from basic research for understanding the process, most of the research this far has been devoted to increasing process performance. Excepting Scarab, the prototype development has also prioritised high efficiency. Scarab has prioritised low capital cost over thermal performance ratio.

Scarab is continuing research in module and membrane efficiency to reduce costs of operation. One type of membrane that is under investigation promises three times the throughput which would reduce present total water cost to less than half

Several tests with industrially made modules have been made. The latest was a 5 000 liter unit that was tested by KTH at a Vattenfall AB power plant for treatment of flue-gas condensate.[2]

This far, Scarab has also delivered equipment to specific demo projects in Sweden, Greece, Spain, United States and Saudi-Arabia and is planning a exhibition plant in Stockholm to be opened to potential customers in 2010. Major water industry integrators, as well as industrial water users and power plant operators will be invited to have a first hand look at the technology.

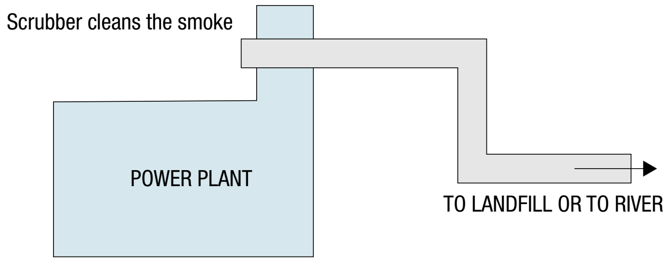
Applications

Since Scarab has chosen a low-cost strategy, the best application for the technology is when waste-heat is available as in polygeneration.

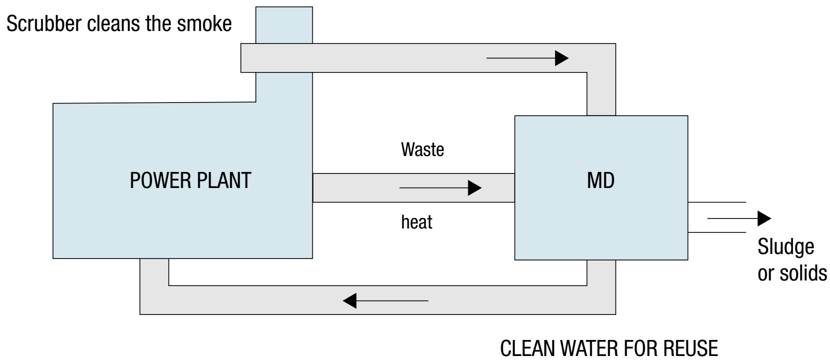
A general characteristic of all MD technology is its advantages when there are difficult feeds to treat. For that reason Scarab has tested industrial effluents and also started working on a few applications with difficult wastes. One example is brine concentration at an RO desalination plant, which is currently tested in Saudi Arabia. Another example is treatment of well water contaminated with arsenic in Bangladesh.

SAVING THE ENVIRONMENT AND SAVING ENERGY

FIRST STEP: NO MORE SMOKE



SECOND STEP: NO MORE WASTE



Scrubber washes out all contaminants from the smoke
Waste heat cleans the scrubber water to Ultra Pure Water standard for feed water use

Purification of flue-gas concentrate (effluence from gas scrubbers in power plants)

In a report regarding treatment of brine with reference to Scarab, MD is described as a promising but yet still emerging technology for water desalination. *WQRA (Water Quality Research Australia), Research Report No 63, Membrane Distillation of Brine Wastes.*

In discussion of energy efficient desalination technology, the report concludes that membrane distillation could reduce baseline energy consumption of public water utilities a great deal and holds up Scarab as pioneers. *EPRI report (Electric Power Research Institute), Program on technology innovation: Electric efficiency through water supply technologies. A roadmap. June 2009.*

Status of Scarab's MD development is described in a publication from the International Desalination Association, www.desalination.biz. *The International Desalination & Water Reuse Quarterly, volume 19, August/September 2009, pages 41 – 46.*

Facilitating the introduction of solar energy

In the search for renewable energy resources, solar power offers a major opportunity. Small solar power systems are installed everywhere. Larger systems are already in place in California and in Spain. Costs have fallen to a point where full commercial viability is less than 5 years away. Major research institutes and corporations are now confidently working together on commercial schemes. They are receiving financial help from official sources either in the way of cash or in generous feed-in or buy-back offers on electricity.

Two processes are making this possible, namely, a decrease in solar power costs and an increase in charges that carbon emitting generation systems have to pay or spend due to environmental legislation. The cost of solar energy in California has fallen to 8-12 US cents per KWh from 24 cents as it was only a few years ago, while coal fired costs are rising from 3 cents to 8 cents if clean coal is generated and carbon credits met. The World Bank estimates that solar power electricty will be fully viable by 2015. The introduction of added benefits from a technology like MD's is likely to help speed up this development.

A drawback with CST (Concentrated Solar Thermal) is that, as with all turbine generators, only a part of the collected heat is transformed into electricity, in general terms about half. In fact, costs are even incurred to dissipate heat from CST. MD can use this (waste) heat commercially to desalinate water and to irrigate for production of food.

Existing desalination systems lead to a water cost of 0.6 (Singapore) to 3.0 Euros (Arizona) per M3. This compares to utility tap water typically costing 0.24 euros per M3 in Chicago and up to 0.82 Euros in Europe. On average desalinated water costs more than tap water in most countries and is being used only where there is water shortage and consumers or municipalities are rich enough to afford it.

MD, if combined with CST, should be able to desalinate at a projected cost of slightly under 0.08 Euros per M3. This would make it suitable for normal drinking purposes for all but also for irrigation of fruits and vegetables.

The two technologies, CST and MD, are both, established, tested and ready for use. Products are on offer to the public that do the job. By the beneficial use of surplus energy from thermal solar power plants and from Photovoltaics, the commercial value of solar electricity installations will be increased which will speed up the introduction of this renewable source of electricity.

Solar desalination - water as important as energy in solar power plants?

A first paper on solar application of Scarab's MD technology was presented in Orlando, Florida in 2005 (Ala'a Kullab et al.)[1]. It shows that although the technology from Scarab (proprietary Air Gap Membrane Distillation) has a potential to be cost efficient, the use of hot water from solar panels is not viable at present because of the high cost of the solar field.

As a consequence of this publication, Scarab was in 2006 invited to participate in an EU-project – MEDESOL - to develop multi-step MD in order to increase efficiency. However, also multi-step MD is still too costly for commercialisation except for specific applications, for instance small installations in remote places. Such an application for MD is also pursued by the Fraunhofer Institute of Germany with support from several EU-contracts.

As it stands, MD is, however, eminently cost competitive if low temperature waste heat is used. One possible application is co-generation with thermal power plants. If, for instance, energy is "borrowed" from a district heating loop, purified water can be produced with almost negligible energy use. This has been studied in a project at the Royal Institute of Technology (KTH) in Stockholm in a project financed by the Swedish Council for Heat Research (Värmeforsk)[2].

In recent years, both, Solar Thermal and Photovoltaics have made much progress. They have moved from demonstration plants to full fledged commercial electricity production and there are many plans worldwide to build more and larger power plants. MD would be equally effective with either.

Scarcity of water and food are mounting problems on which we are all agreed. There are shortages of drinking water in many places and this situation is likely to grow. Moreover, climate change is depleting glaciers that supply water to many leading rivers and groundwater sources are being severely strained.

Everybody is agreed that desalination is one of the major potential solutions to the water problem but it has so far been too expensive to be used far more widely. The combination of Concentrated Thermal and MD are projected to allow sustainable electricity at below 8 US cents per KWh and pure water at less than 0.1 Euro per M3.

With these prices, the market for sustainable electricity and cheap desalinated water is likely to be substantial.

Water for irrigation is one of the greatest future challenges for sustainability.

> "Obviously there are many drivers of human development," says the UN's Andrew Hudson. "But water is the most important." At the United Nations Development Programme (UNDP), where Dr Hudson works as principal technical advisor to the water governance programme, he calculated the contribution that various factors make to the Human Development Index, a measure of how societies are doing socially and economically. "It was striking. I looked at access to energy, spending on health, spending on education - and by far the strongest driver of the HDI on a global scale was access to water and sanitation." BBC News, 2009/02/02

> "Let me be very clear. There is no development without water. There is no food security without water. There is most likely also no energy security without water. Water is the primary medium through which climate change influences the Earth's ecosystems and therefore people's livelihoods and well-being. If water is not further recognized in adaptation strategies and plans, we are making a big mistake." Pasquale Steduto, Chair, UN-Water and Service Chief, FAO

The analyses having been done by Scarab over future water costs shows that it under all scenarios is within a range that is far below current desalination costs by a large factor. It also suggest that MD desalinated water, once the technology is fully developed could be used for irrigation.

Implementation

Scarab has held discussions with leading international companies and research institutes both in the fields of energy and water for some years. Commercial exploitation will be made with one or several large partners.

At present Scarab equipment is being tested for treatment of RO concentrate in Saudi-Arabia. The ultimate target for this project is Zero Liquid Discharge with a combination of MD and Crystallizer/Evaporator. This will enable sustainable treatment of high salinity ground-water and beneficial use of any type of brine.

The next step for Scarab is a test of the combination of Concentrated Solar and MD. The high temperatures in large scale solar power plants will need efficient cooling for which MD is perfect – with pure water as a by-product. This will fit in well with the European Desertec project as well as other large scale solar power projects being implemented or planned in the United States, China, Australia, the Middle East, North Africa and India.

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SMALL SCALE POLYGENERATION